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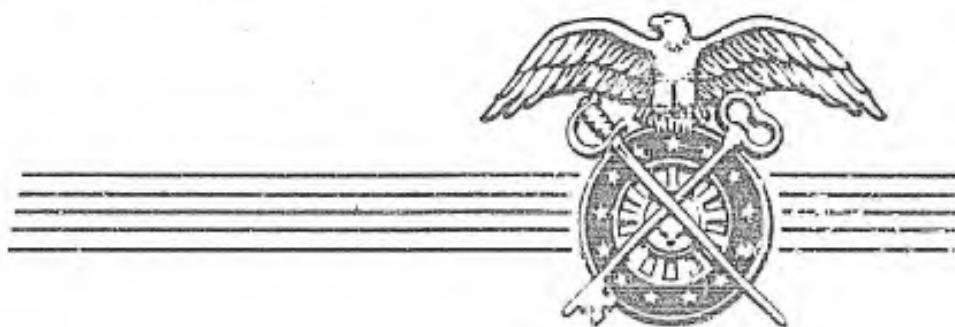
TECHNICAL REPORT

EP-87

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BAC

Canal Zone Analogs I

ANALOGS OF CANAL ZONE CLIMATE  
IN  
MIDDLE AMERICA



QUARTERMASTER RESEARCH & ENGINEERING CENTER  
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

APRIL 1958

NATICK, MASSACHUSETTS

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Quartermaster Research & Engineering Center  
Natick, Massachusetts

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report

EP-87

CANAL ZONE ANALOGS NO. I

ANALOGS OF CANAL ZONE CLIMATE IN MIDDLE AMERICA

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Vicksburg, Mississippi

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## FOREWORD

A successful research, development, or training program requires a knowledge of the degree of environmental representativeness of test sites and training areas. The Quartermaster Corps, at the request of the Corps of Engineers, Waterways Experiment Station, under a directive from the U.S. Army General Staff, is developing a generalized comparative climatic picture of the wet-tropics throughout the world by a series of tropical analog studies. The series parallels another already completed, presenting comparisons between Yuma, Arizona, and the various desert regions of the Northern Hemisphere.

This is the first of the tropical series. It compares the Canal Zone climate with that of the rest of Middle America, and by so doing provides a climatic reference for military planners and test personnel.

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## ABSTRACT

~~This study compares~~ the climate of Middle America with that of two locations in the Canal Zone: Balboa Heights, representing the drier leeward Pacific side of the Isthmus of Panama; and Cristobal, representing the wetter windward Atlantic side. Distribution of areas of analogy of pertinent climatic elements and combinations is shown in maps. The areas of close climatic analogy of combinations of climatic elements (temperature and precipitation) to the Canal Zone are generally small; even the largest area of composite analogy with Cristobal includes only the Atlantic coastal lowlands from Bluefields, Nicaragua to the Panama — Colombia border. ~~Some individual climatic elements, however, show extensive analogy;~~ the area with summer temperatures analogous to those of Cristobal extends throughout nearly all of Middle America and much of the United States. North of latitude 18°N and in highland areas, temperatures for the coldest month are much lower than those of either Balboa Heights or Cristobal.

Annual rainfall is closely analogous to that of Balboa Heights in part of the Gulf coast of southeastern United States, and in southern Mexico, Central America, and the Caribbean Islands. Areas as wet as Cristobal are smaller. The wettest areas are also the cloudiest.

The area analogous to Cristobal with respect to relative humidity for the driest month extends, in general, along the Atlantic coast, and includes the islands of the West Indies; ~~the interior and highland areas are not sufficiently humid to be analogous to either Balboa Heights or Cristobal. The coastal plains and lowland are windiest where there are few topographic obstructions.~~



## ANALOGS OF CANAL ZONE CLIMATE IN MIDDLE AMERICA

### 1. Purpose and scope

This report is the first of a series comparing the climate of tropical regions with that of Cristobal and Balboa Heights, Canal Zone. These two stations were selected to represent the climates of the Atlantic and Pacific portions of the Canal Zone, respectively. The environment of Cristobal is described in a previous report (Wiley and others, 1955).

No attempt has been made to provide a regional climatology of Middle America. Rather, the method has been to select certain climatic elements that are considered particularly significant and, for each of these, to map the areas within the region considered closely analogous to either Balboa Heights or Cristobal. Some of the information presented on these maps of single climatic elements has been consolidated into two composite maps, one for each of the two Canal Zone stations, showing areas where there is a coincidence of analogy for up to four climatic elements. The basic approach of this study parallels that used in the Yuma, Arizona, analog series, although some of the climatic elements used for comparison differ from those used in the Yuma studies.

### 2. Delimitation and topography of Middle America

"Middle America", as usually defined, comprises Central America, Mexico, and the West Indies. The southeastern United States, with tropical heat in summer, also has been included on the maps.

Most of the Middle America study area falls within five major regions: the Greater Antilles, the Lesser Antilles, Central America, the Atlantic and Gulf coastal plains of the southeastern United States, and Mexico.

The Greater Antilles include Cuba, Jamaica, Hispaniola (Haiti and the Dominican Republic), and Puerto Rico. Cuba has low relief and elevation in all parts except the southeastern end of the island, consisting of plains and occasional hills and low mountain ranges. Jamaica has moderately high average slope and elevation, with the Blue Mountains in the east rising to 7,000 feet; the remainder is largely dissected plateau. Narrow plains are found along the north coast and portions of the southwest coast; together with small intermontane basins and irregular valleys they comprise the lowland portion of the island. Hispaniola is characterized by a series of generally east-west ranges with elevations up to 10,249 feet. The ranges are separated by long valleys, often forming extensive basins. Moderately wide coastal plains are found on the northwest and southeast portions of the island. Puerto Rico has a low, mountainous backbone, broad coastal plains in the north, and relatively narrow coastal plains elsewhere.

The Lesser Antilles form a major volcanic arc in which only a few volcanoes are still active. Most of the islands are mountainous, and have coastal plains which vary widely in area. Dominica, Martinique, St. Vincent, and St. Lucia consist almost entirely of steeply sloping upland; Barbados, Barbuda, and St. Croix, on the other hand, consist largely of flat to gently rolling plains and low limestone terraces.

Outlying West Indian islands, sometimes regarded as part of the Lesser Antilles, include Curaçao, Aruba, Bonaire, and Trinidad. All but the last-named are primarily low, limestone platforms. Trinidad is geomorphically an extension of Venezuela; its Northern Range is a continuation of the Andean tectonic system, while the central and southern portions are a slightly upraised continuation of the Orinoco lowlands.

Central America is predominantly mountainous; elongated, often high ranges, with a general east-west trend, extend from southern Mexico to Colombia. Two distinct breaks in the mountains occur, one on the Costa Rica-Nicaragua border and the other at the Panama Canal. In Nicaragua, Honduras, Guatemala, and British Honduras, the Caribbean coastal plain is variable in width. The widest plains extend north-south. Lowland indentations locally extend more than 100 miles inland. In Panama and on the Pacific sides of Costa Rica, Nicaragua, El Salvador, Guatemala, and southern Mexico, the mountains tend to parallel the coast and to reach their highest elevations, more than 11,000 feet in places. Parallel to this nearly continuous range is a moderately narrow coastal plain, becoming relatively broad in Guatemala and Honduras, and narrower in Costa Rica.

A portion of Southeastern United States is included in this study in order to show the northern continuation of the areas of analogy of various climatic elements. The area includes the south Atlantic and Gulf coastal plains, the low hilly zones behind them, and the Appalachian Mountains.

The dominant feature of northern Mexico is a broad plateau which narrows southward and gives way to dissected mountains. To the north it merges with the plateaus of southwestern United States. Elevation of the plateau declines from an average of 7,000 feet in the south to about 4,000 feet at the United States border. Slopes are steep in the southern portion; in the Gulf of Mexico section the plateau edge is dissected into numerous deep valleys; and the Pacific section is a broad zone of sharply dissected upland. The plateau surface (as in the Valley of Mexico, a basin with an average elevation of 7,500 feet) is rimmed by high volcanic mountains which reach elevations of 17,880 feet. Broad, low-lying plains rim the Gulf coast from Yucatan to Texas; somewhat narrower plains border the Pacific from the Isthmus of Tehuantepec to Guatemala. The Yucatan Peninsula is a low, rolling platform, composed largely of limestone, much like Florida and Cuba.

### 3. Climatic summary of the Canal Zone

The Pacific portion of the Canal Zone, represented by Balboa Heights, has a moderately humid, tropical climate (see Figure 1). The difference in mean monthly temperature of the warmest and coldest months is only 2°F, and the range from the highest mean daily maximum (March and April, 90°F) to the lowest mean daily minimum (February, 71°F) is only 19°F. Also, the mean annual temperature of 79°F is typical of equatorial areas. Precipitation, averaging 70 inches annually is markedly seasonal. Two months, February and March, have less than 1 inch of rainfall, and 5 months have more than 8 inches. The dry season begins in December and ends in April. Rainfall during the remaining months varies from 7 to 10 inches, with a maximum in October and November, each of which has more than 10 inches. Relative humidity is high in all months from June through November. Cloudiness reaches a maximum from May through November, coinciding with the wet season, with an average of about 0.8 of sky covered at Balboa Heights at that season. Wind speed, however, is greatest during the dry season, with winds averaging 9 to 10 mph at Balboa Heights from January through April but only about 5 to 6 mph during the remainder of the year. Southeastward toward the coast, there is a slight decrease in rainfall and increase in temperature, as elevation drops from the 118 feet at Balboa Heights. Rainfall increases to the northwest, averaging 88 inches at Gamboa, 117 inches at Monte Lirio, and more than 130 inches at Cristobal.

The Atlantic portion of the Canal Zone, represented by Cristobal, has a wet-tropical climate (Figure 1). The difference in mean temperatures of the warmest and coolest months is only 2°F, and the range from the highest mean daily maximum (April, May, June, September, and October, 86°F) to the lowest mean daily minimum (October and November, 75°F) is only 11°F. The mean annual temperature of 81°F is typical of equatorial areas. Precipitation averages 130 inches a year, and the monthly distribution is uneven although no month can be considered really dry; 2 months have less than 2 inches of rainfall, while 8 months have more than 11 inches. The drier season at Cristobal begins in January (3.4 inches) and ends in April (4.1 inches). During the remaining months, average rainfall ranges from nearly 12 to a maximum of more than 22 inches in November. Mean relative humidity is high in all months; the lowest mean value, 77 percent, is in both February and March. Cloud cover is greatest in July, 0.8, and least in February, 0.55. Wind speed is greatest in February and March (nearly 15 mph) and least in September (about 6 mph).

### 4. Criteria and methods.

#### a. Climatic elements selected for study

Temperature, precipitation, humidity, cloud cover, and wind speed were the climatic elements considered most important to military activities. It was assumed that test authorities are more interested in stress periods (e.g., hottest and wettest) and annual fluctuations than in the data for

# CRISTOBAL

(ATLANTIC SIDE)

# BALBOA HEIGHTS

(PACIFIC SIDE)

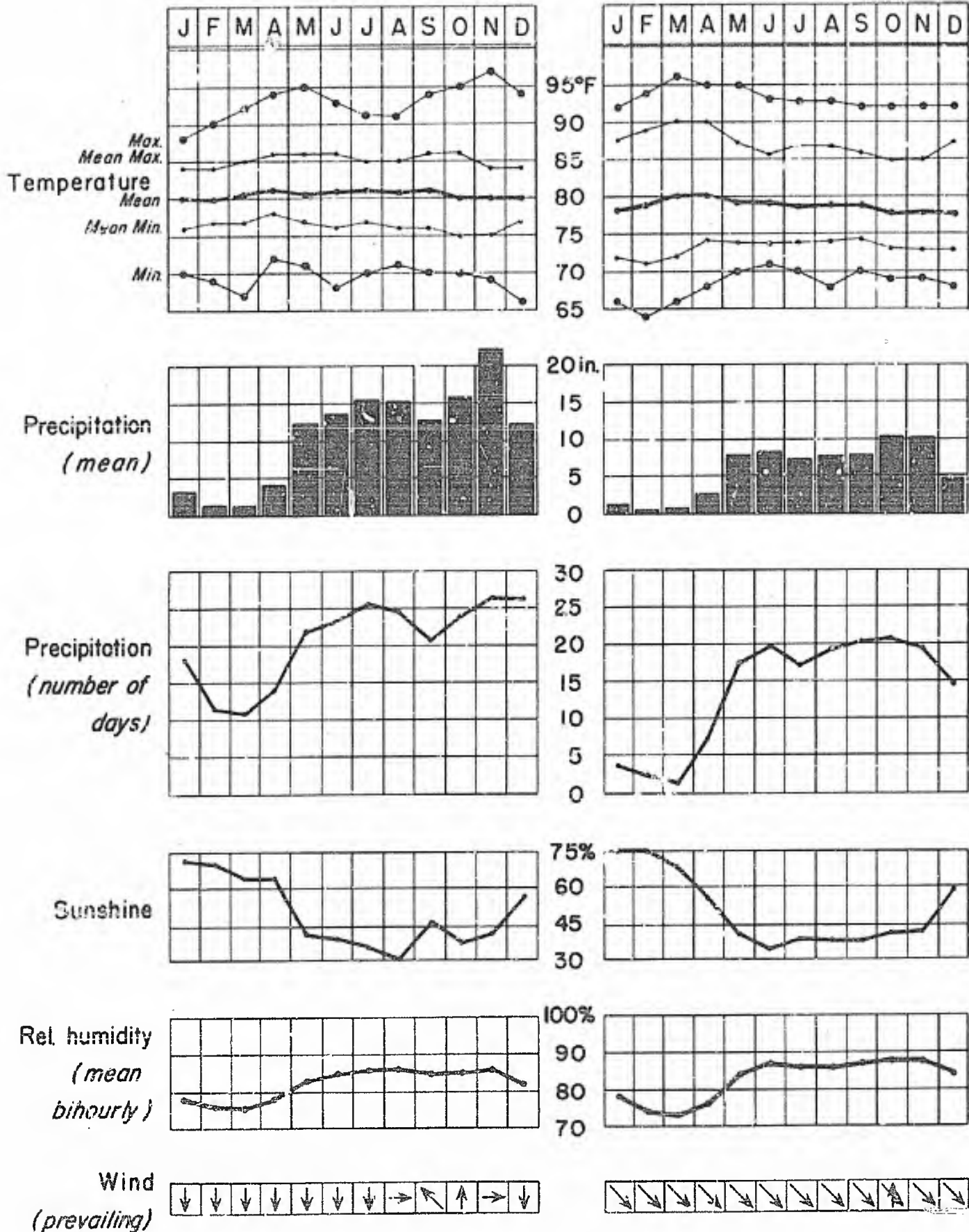


Figure 1. Climatic Summary

specific calendar months; accordingly, the warmest, coldest, wettest, and driest months of the year at each station were selected for study. The following specific combinations of element and month were studied: mean temperature of the warmest month, mean daily maximum temperature of the warmest month; mean daily temperature range of the warmest month, mean temperature of the coldest month, mean daily minimum temperature of the coldest month, mean annual precipitation, mean precipitation of the wettest month, mean cloud cover of the wettest month, mean wind speed of the wettest month, mean relative humidity of the driest month, and number of wet months.

b. "Analogous" and "semianalogous": ranges defined

Classes were established defining the ranges of values considered closely analogous to those for Balboa Heights and Cristobal. Fairly narrow limits of analogy were used in order to keep comparisons closely representative of the two reference stations. Table I lists the classes of analogy and semianalogy selected for each element. For temperature, a departure of 4 degrees (except where a mean was taken for the two reference stations) from the mean at the Canal Zone station was allowed for each analogy class and an additional 4 degrees for semianalogy. For precipitation, departures of 15 inches of mean annual rainfall were considered analogous to Balboa Heights and an additional 15 inches for semianalogy. The mean annual rainfall of 70 inches at Balboa Heights is somewhat below that normally considered equatorial (supporting dense evergreen rain forest); therefore, in this tropical deciduous forest the limits of analogy were set at 55 to 85 inches, differentiating it from most of the evergreen rain forest areas, on the upper margin, and savanna areas, on the lower margin. Cristobal, a tropical evergreen rain forest type, has a mean annual rainfall of 130 inches. Departures of 30 inches of mean annual rainfall were considered analogous to Cristobal and an additional 30 inches for semianalogy. Departures of 5 percent in mean relative humidity, one-tenth in amount of cloudiness, and 2 mph in wind speed were selected as ranges of analogy for these elements.

c. Mapping analogies

Values were plotted for each station, with degree of analogy indicated by a symbol. Isopleths were drawn to show zones of close analogy, and these areas were shaded. Areas of semianalogy were indicated by placing the appropriate symbol on the map and legend for stations having semi-analogous conditions, but were not shaded. From the separate maps showing analogous areas for each element, 2 composite maps were prepared (one for Balboa Heights and one for Cristobal) indicating regions where the following four single elements are analogous: mean temperature of warmest month, mean temperature of coldest month, mean annual precipitation, and number of wet months.

#### d. Limitations of data

The procedures as outlined have certain definite limitations in a climatic comparison of this sort. Foremost among these is the necessity, often encountered in climatology, of assuming climatic conditions in areas having few if any stations.

A second limitation is that some elements, such as dew point, radiation, and visibility, which would have proved valuable as indicators of climatic analogy, were not included in this study because of the limited amount of data available. Dew points could have been approximated from mean relative humidity and mean temperature, but it was felt that the original relative humidity data were not sufficiently accurate to warrant this. Moreover, for certain elements the number of stations reporting do not provide a representative picture. Consequently, isopleths were not drawn for mean relative humidity of the driest month, mean cloudiness of the wettest month, or mean wind speed of the wettest month.

The assumption has been made that Balboa Heights and Cristobal are representative of the Pacific and the Atlantic portions of the Canal Zone. Other stations, with slightly different climates, might equally well have been chosen.

Data from some Middle American stations are not given in a form directly comparable to the Balboa Heights and Cristobal records. Where period of record, hours of observation, or manner of observation differed, station records had to be interpreted in drawing the isopleths.

Values outside the limits of analogy or semianalogy were not analyzed nor were combinations of climatic elements other than those involved in computing number of wet months.

A special problem was encountered in the Lesser Antilles. Here, long records are normally available for one station on each island, commonly on the leeward side where the chief town and port is usually situated. Such records are clearly unrepresentative of the entire island, except in the case of a few islands with low relief, such as Barbados, St. Croix, and Antigua. Islands such as Dominica and St. Vincent have moderate rainfall on the windward (Atlantic) side, very high rainfall in the interior highlands, and relatively low rainfall on the leeward (Caribbean) side. Temperature ranges are correspondingly lower in the windward and upland portions, with lower maxima and higher minima. Also, humidities, wind speed, and cloudiness are higher on the windward and upland portions. Analogous areas are small in the Lesser Antilles, not only because of these differences but also because topographic diversity produces major changes in conditions over areas too small to be mapped in this study. In the Bahamas where relief is low, the values for Nassau (a first-order station) are used to represent almost the entire island



group. In the Netherlands West Indies, values for Willemsted on Curaçao are taken as representative of the Dutch islands off the Venezuelan coast (Curaçao, Aruba, and Bonaire).

The method of recording temperatures varies from country to country. Mean temperatures are usually determined by averaging the daily maximum and minimum temperature; however, at some stations in the United States the means are obtained by averaging hourly temperatures. At Balboa Heights and Cristobal the mean temperature is determined by averaging bi-hourly temperature observations. Experience has shown that the difference between mean temperatures derived in these different ways is seldom more than 1 F° (Contreras Arias, 1942). Hours of observation of relative humidity, wind speed, and cloudiness vary widely throughout Middle America.

##### 5. Analysis of single-element maps

Individual maps showing analogous areas have been prepared for the following climatic elements:

- Mean temperature of the warmest month
- Mean daily maximum temperature of the warmest month
- Mean temperature of the coldest month
- Mean daily minimum temperature of the coldest month
- Mean daily temperature range of the warmest month
- Mean annual precipitation
- Mean precipitation of the wettest month
- Number of wet months.

Maps of the following were prepared, showing only the values for individual stations, since the data were considered inadequate for delimiting analogous areas:

- Mean relative humidity of the driest month
- Mean cloudiness of the wettest month
- Mean wind speed of the wettest month

##### a. Mean Temperature, Warmest Month (Fig. 3)

Balboa Heights (March and April, 80°F) and Cristobal (April, 82°F) have nearly the same mean temperature for the warmest month. In order to show a single analogous area for this element, a range of 4° on either side of 81°F is considered analogous for purposes of this study. Areas falling within this range are shaded on the map. An additional 4° above 85°F and below 77°F is considered semianalogous. Stations having semianalogous conditions are designated on the map by an appropriate symbol, but the areas that are represented are not shaded.

Nearly all of Middle America and the southeastern United States is analogous to the Canal Zone in summer temperatures. Stations where the mean temperatures are too high for analogy in the warmest month are found in only a few areas all distant from the east coast, chiefly in the deserts to the north, the Gulf of California littoral south to 25°N, the Balsas River basin in Mexico, and much of the lower Rio Grande valley. The Mexican Plateau, the mountainous areas of the Caribbean islands, and the Central American highlands are either semianalogous on the cooler side, or too cool for any degree of analogy.

b. Mean Daily Maximum Temperature, Warmest Month (Fig. 4)

At Balboa Heights the mean daily maximum temperature for the warmest month (March and April) is 90°F, whereas at Cristobal it is 86°F (April, May, June, September, and October). Areas that fall within 4° on either side of the mean are considered analogous. Most of the coastal areas of Middle America are analogous except those bordering the Gulf of California. The arid lands of the southwestern United States and northern Mexico are much hotter in summer than the Canal Zone, and the higher elevations are much cooler. A considerable intermediate area, and most of the eastern half of the United States, extending far north of the limits of the study area, are analogous.

c. Mean Temperature, Coldest Month (Fig. 5)

Balboa Heights and Cristobal have nearly the same mean temperature for the coldest month, 78° and 80°F respectively. A range of 4° on either side of 79°F is considered analogous, giving a single analogous area for this element. The Pacific shore of southern Mexico, the coastal lowland of Central America, and the Caribbean islands except for most of Cuba and Hispaniola are analogous. In general, the highlands and the areas north of 18°N are too cold in winter to be analogous.

d. Mean Daily Minimum Temperature, Coldest Month (Fig. 6)

At Balboa Heights the mean daily minimum temperature for the coldest month (February) is 71°F, whereas at Cristobal it is 75°F (October). Closely analogous areas are those with temperatures that fall within 4° on either side of the above two means. Only the southern coasts of Mexico, and the coastal areas of Central America and the Caribbean islands, except Cuba, are analogous to Balboa Heights, the remainder of the study area being too cold for analogy in the coldest month. No part of the study area is warm enough in the coldest month to be analogous to Cristobal alone, but there is some overlapping of the areas of analogy with Cristobal and Balboa Heights in the coastal lowlands.



e. Mean Daily Temperature Range, Warmest Month (Fig. 7)

At Balboa Heights the mean daily temperature range for the warmest month is 16 F° (April), whereas it is 8 F° (April) at Cristobal. Temperatures within 4° of these two means are considered analogous. Interior and highland areas have too high a temperature range to be analogous to either Balboa Heights or Cristobal. Low mean daily temperature range is largely confined to areas exposed to the coasts except for an area in the southeastern United States.

f. Mean Annual Precipitation (Fig. 8)

At Balboa Heights the mean annual precipitation is 70 inches; at Cristobal it is 130 inches. Stations with mean annual precipitation between 100 and 160 inches are considered analogous to Cristobal, whereas those with 55 to 85 inches are considered analogous to Balboa Heights. There are numerous areas analogous to Balboa Heights in the Gulf section of the southeastern United States and in southern Mexico, Central America, and the Caribbean islands. There are smaller areas analogous to Cristobal, principally at intermediate elevations from southern Mexico to Panama, and in the Caribbean islands from Puerto Rico to Trinidad.

g. Mean Precipitation, Wettest Month (Fig. 9)

As the wettest month is a time of maximum stress in the wet tropics, a separate analysis was made of mean precipitation for that month. At Balboa Heights the mean precipitation for the wettest month (November) is 11 inches, whereas for Cristobal it is 22 inches (November). At Balboa Heights, 3 inches on either side of the mean is considered analogous; at Cristobal, 7 inches on either side of the mean is considered analogous. The area of analogy is greater for this criterion than for mean annual precipitation. It includes most of the Pacific and Gulf coasts of Mexico, and widens out in Central America to include the interior lowlands.

h. Number of Wet Months (Fig. 10)

A wet month is defined as one with rainfall greater than the values given in the following sliding scale, which allows for the lesser effectiveness of rainfall as temperatures rise.

<u>Mean monthly temperature (°F)</u>	<u>Mean monthly precipitation (in.)</u>
95	2.88
90	2.71
85	2.54
80	2.37
75	2.20
70	2.03
68	1.96

These values are based on the Thornthwaite (1931) formula. Wet months with mean monthly temperatures below 68°F are excluded from the map as being nontropical. Balboa Heights has 9 wet months, and Cristobal has 10. Stations with 8 to 10 wet months are considered to be analogous to Balboa Heights; those with 9 to 11 wet months are considered analogous to Cristobal. In Middle America there are many areas of analogy; the largest extends from the Gulf coast of southern Mexico southeast along the Caribbean coast across Panama to South America. There is an analogous area on the Pacific coast from the southern tip of Mexico to the Pacific lowlands of Guatemala. Parts of the southern coasts of Cuba, Jamaica, Hispaniola, Puerto Rico and western Central America have an appreciably longer dry period than either Canal Zone station, while most of the United States and Mexico are nonanalogous because of the large number of insufficiently hot months.

i. Mean Relative Humidity, Driest Month (Fig. 11)

At both Balboa Heights and Cristobal the driest month is February with relative humidities of 75 and 77 percent, respectively. Five percent on either side of the two means is considered analogous to both stations. For purposes of this study the mean relative humidity for the driest month was selected instead of that for the wettest month, because greater variations are to be expected in the drier season. During rain, relative humidity will often rise to 100 percent. Because the climatic data for this element are not recorded at all stations and the hours of observation are not uniform, isopleths were not drawn on the map. Only the station data are plotted for this element. In general, the coastal areas and islands are analogous, while the interiors and highlands have lower humidity.

j. Mean Cloudiness, Wettest Month (Fig. 12)

At both Balboa Heights and Cristobal the mean cloudiness for the wettest month (November) is approximately 0.7 of sky coverage. Sky cover within one-tenth of the mean either way is considered analogous to both Canal Zone stations. Because data for this element are not recorded at all stations, and the hours of observation are not uniform, isopleths were not drawn on the map. Only the station data are plotted. In general, the wettest areas are also the cloudiest.

k. Mean Wind Speed, Wettest Month (Fig. 13)

At Balboa Heights the mean wind speed for the wettest month (November) is nearly 6 mph whereas at Cristobal it is 8 mph (November). A range of 2 mph on either side of the two means for both stations is considered analogous. The analogous areas for this element were not drawn, because the hours of observation are not uniform at all stations. In general, the coastal and lowland areas that are exposed to the northeast trade winds are the windiest.

## 6. Analysis of composite maps

Composite maps were drawn to show the areas with climate most closely analogous to that at Balboa Heights (Fig. 14) and Cristobal (Fig. 15). The following elements were selected as most significant: mean temperature of the warmest and coldest months, mean annual precipitation, and number of wet months.

On the Balboa Heights map there are 4 small areas in Central America having analogous conditions for all of these elements. In addition, there are numerous small areas of analogy in the islands of the West Indies.

On the Cristobal map nearly all of the Caribbean coast south of Honduras is shown as analogous, but elsewhere except for northeastern Trinidad there are no analogous areas.

In general, the areas analogous to Balboa Heights are leeward, and those analogous to Cristobal are windward.

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## APPENDIX A

### Tables of Monthly Values

Tables III through IX show the month-by-month variation in the climatic elements considered in this report. The tables show mean values of these elements for all months at 20 stations representing various parts of the study area. The record at Washington, D.C., is included for comparison. The stations are listed, together with their coordinates, elevations, and periods of record, in Table II. In each table the mean values for Balboa Heights and Cristobal are shown for comparison.

Inspection of the tables reveals characteristics of climatic analogy that are not evident in the maps. For example, the precipitation values on Figure 8 are just annual means whereas Table VI gives some information about the distribution of the precipitation for each month throughout the year. The lengths of dry and wet seasons, and temperature differences between seasons, can be noted from the tables. A comparison of various elements by months can readily be made by using the tables.

TABLE I: CLIMATIC ELEMENTS AND CLASSES OF ANALOGY

Station index	Value at Balboa Heights		Balboa Heights		Value at Cristobal		Cristobal	
	Balboa Heights	Range	Analogue	Range	Cristobal	Range	Semianalogue	Range
TEMPERATURE (F)								
Mean, warmest month*	80°	77°-85°	73°-76°	86°-89°	82°	77°-85°	73°-76°	86°-89°
Mean daily maximum, warmest month	90°	86°-94°	82°-85°	95°-98°	86°	82°-90°	78°-81°	91°-94°
Mean, coldest month*	76°	75°-83°	71°-74°	84°-87°	80°	75°-83°	71°-74°	84°-87°
Mean daily minimum, coldest month	71°	67°-75°	63°-66°	76°-79°	75°	71°-79°	67°-70°	80°-83°
Mean daily range, warmest month	16°	12°-20°	8°-11°	21°-24°	8°	4°-12°	0°-3°	13°-16°
PRECIPITATION								
Mean annual (inches)	70	55-85	40-54	86-100	130	100-160	70-99	161-190
Mean wettest month (inches)	11	8-14	5-7	15-17	22	15-29	8-14	30-36
Number of wet months	9	8-10	7	11	10	9-11	8	12
RELATIVE HUMIDITY								
Mean, driest month	75%	70-80%	65-69%	81-85%	77%	72-82%	67-71%	83-87%
CLOUDINESS								
Mean, wettest month (tenths)	7	6-8	5	9	7	6	5	9
WINDSPEED								
Mean, wettest month (MPH)	6	4-8	2-3	9-10	8	6-10	4-5	11-12

\*See sec. 5 for explanation of ranges of analogy

TABLE II: STATIONS USED IN TABLES OF MONTHLY VALUES

Station	Elevation (in feet)	Latitude (N)	Longitude (W)	Period of Record (yrs)		
				Temp.	Prec.	Other
Acapulco (Mexico)	10	16° 49'	99° 55'	8	8	4-8
BALBOA HEIGHTS (C.Z.)	118	8° 58'	79° 35'	12-34	22-38	11-34
Belize (Brit. Hon.)	17	17° 30'	88° 10'	24	41-42	5-17
Bluefields (Nicaragua)	17	12° 01'	83° 45'	8-11	11	11
Brownsville (Texas)	16	25° 54'	97° 26'	74	74	16-74
Camaguey (Cuba)	393	21° 30'	77° 59'	13	17-20	4-86
Ciudad Trujillo (Dom. Rep.)	69	18° 28'	69° 54'	26	25	4-8
CRISTOBAL (C.Z.)	36	9° 25'	79° 52'	7-32	8-60	3-41
David (Panama)	33	8° 22'	82° 30'	8	8	8
Habana (Cuba)	80	23° 08'	82° 21'	60	72	20-53
Kingston (Jamaica)	110	17° 59'	76° 50'	33	30-53	7-16
Miami (Florida)	8	25° 47'	80° 11'	45	45	16-45
Nassau (Bahama Is.)	8	25° 03'	77° 20'	15	52-64	3-44
New Orleans (Louisiana)	9	29° 57'	90° 04'	82	85	16-85
Port-au-Prince (Haiti)	121	18° 35'	72° 20'	42	65	8-46
Port of Spain (Trinidad)	72	10° 40'	61° 31'	40	40-71	3-41
San José (Costa Rica)	3,760	9° 58'	84° 02'	5-12	8-34	3-16
San Juan (Puerto Rico)	82	18° 28'	66° 07'	25	25	11-39
Santiago (Cuba)	82	20° 00'	75° 50'	16	16	3-11
Tela (Honduras)	-	15° 46'	87° 27'	13	6	5-8
Valladolid (Mexico)	59	20° 41'	88° 12'	-	-	-
Vera Cruz (Mexico)	52	19° 12'	96° 08'	12	12-30	6-30
Washington, D.C.	72	38° 54'	77° 03'	66	66	66

TABLE III: MEAN MONTHLY TEMPERATURE (°F)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Acapulco	78	73	79	80	83	83	83	83	82	82	81	79	81
BALBOA HEIGHTS	78	79	80	80	79	79	79	79	79	78	78	78	79
Belize	74	76	77	80	81	81	81	81	82	79	76	74	78
Bluefields	78	78	81	82	81	79	79	79	79	80	79	78	80
Brownsville	61	63	68	74	79	83	84	84	81	76	68	62	74
Camaguey	72	73	76	78	79	80	82	82	80	79	76	73	77
Ciudad Trujillo	75	76	76	77	78	80	80	80	80	80	78	76	78
CRISTOBAL	80	80	81	82	81	81	81	81	81	80	80	80	81
David*	-	-	-	-	-	-	-	-	-	-	-	-	-
Habana	72	72	74	76	79	81	82	82	81	79	75	73	77
Kingston	76	76	77	78	80	81	81	81	81	79	78	77	79
Miami	69	69	71	74	77	80	82	82	81	78	72	70	75
Nassau	71	72	73	75	78	80	82	82	82	80	76	73	77
New Orleans	56	59	63	70	76	82	83	83	80	73	63	57	70
Port-au-Prince	78	78	79	80	81	82	84	83	82	81	80	78	80
Port of Spain	76	76	79	78	80	79	78	77	80	80	78	78	78
San José	66	67	68	69	69	68	68	68	68	67	67	66	67
San Juan	75	74	75	76	78	80	80	80	80	80	78	76	78
Santiago	75	75	76	78	80	80	82	82	81	80	78	76	79
Tela	74	76	77	79	81	81	81	81	81	79	77	75	78
Valladolid	72	73	76	80	81	80	80	80	79	77	74	73	77
Vera Cruz	70	71	73	77	80	81	81	81	80	79	75	72	77
Washington	37	38	46	55	65	74	78	76	70	58	48	38	57

TABLE IV: MEAN DAILY MAXIMUM TEMPERATURE (°F)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Acapulco	86	86	87	88	90	89	90	90	88	88	88	88	88
BALBOA HEIGHTS	88	89	90	90	87	86	87	87	86	85	85	87	87
Belize	80	82	84	86	87	87	87	88	88	86	84	81	85
Bluefields	83	84	86	87	88	87	85	86	88	88	86	83	86
Brownsville	70	73	77	83	88	96	92	93	90	85	76	71	82
Camaguey	81	83	86	89	89	89	91	91	90	87	84	82	87
Ciudad Trujillo	84	85	84	85	86	87	88	88	88	87	86	85	86
CRISTOBAL	84	84	85	86	86	86	85	85	86	86	84	84	85
David*	-	-	-	-	-	-	-	-	-	-	-	-	-
Habana	79	79	81	84	86	88	89	89	88	85	81	80	84
Kingston	86	86	86	87	87	89	90	90	89	88	87	87	88
Miami	74	75	77	80	82	85	87	87	86	83	78	75	81
Nassau	76	77	78	80	83	86	88	88	87	85	80	77	82
New Orleans	64	67	71	78	84	89	90	91	87	80	70	65	78
Port-au-Prince	87	88	89	89	90	92	94	93	91	90	88	87	90
Port of Spain	85	86	87	88	89	87	87	87	88	88	87	86	87
San José	75	78	80	78	78	76	75	75	75	75	75	73	76
San Juan	80	80	81	82	84	85	85	85	86	86	84	81	83
Santiago	83	83	84	85	86	87	89	90	88	87	85	83	86
Tela	82	84	84	88	91	89	88	89	90	87	83	83	86
Valladolid	82	85	88	91	92	90	90	90	89	87	84	82	88
Vera Cruz	74	76	78	81	84	85	85	86	85	84	80	76	81
Washington	44	46	55	65	76	84	87	85	79	68	57	46	66

\*No data available



TABLE V: MEAN DAILY MINIMUM TEMPERATURE (°F)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Acapulco	69	68	69	72	75	75	75	75	75	74	72	70	72
BALBOA HEIGHTS	72	71	72	74	74	74	74	74	74	73	73	73	73
Belize	67	69	71	73	77	75	76	75	75	72	69	68	72
Bluefields	70	70	70	72	73	73	73	73	73	72	71	71	72
Brownsville	51	54	60	66	70	75	76	75	73	66	59	53	65
Camaguey	63	64	66	68	70	71	72	72	71	70	67	64	68
Ciudad Trujillo	66	66	67	69	71	72	72	73	72	72	70	67	70
CRISTOBAL	76	77	77	78	77	76	77	76	76	75	76	77	76
David*	-	-	-	-	-	-	-	-	-	-	-	-	-
Habana	65	65	67	69	72	74	74	75	74	73	69	67	70
Kingston	67	67	68	70	72	74	73	73	73	73	71	69	71
Miami	63	63	65	69	72	75	76	77	76	73	67	64	70
Nassau	67	67	68	69	72	75	76	77	76	75	71	69	72
New Orleans	48	50	55	62	68	74	76	76	73	65	55	50	63
Port-au-Prince	68	68	69	71	72	73	74	73	73	72	71	69	71
Port of Spain	67	67	67	69	70	71	70	71	71	71	70	69	69
San José	59	60	61	63	63	63	63	62	62	62	61	61	62
San Juan	70	69	70	71	73	75	75	76	75	74	73	71	73
Santiago	68	68	69	71	73	74	75	75	74	73	71	69	72
Tela	67	67	68	69	72	72	70	71	71	71	68	69	70
Valladolid	63	63	65	68	71	72	71	71	72	69	65	64	68
Vera Cruz	65	67	69	73	76	76	74	75	74	74	70	67	73
Washington	29	29	36	45	55	64	68	67	61	49	33	31	48

TABLE VI: MEAN MONTHLY PRECIPITATION (inches)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Acapulco	0.4	0.0	0.0	0.0	1.1	16.9	8.5	9.7	14.1	7.5	1.2	0.4	59.2
BALBOA HEIGHTS	1.0	0.6	0.7	2.9	8.0	8.4	7.3	7.8	8.2	10.2	10.5	4.7	70.3
Belize	6.6	2.8	1.8	2.8	5.8	9.8	7.7	7.8	9.2	13.2	10.5	7.7	71.4
Bluefields	5.7	7.0	3.5	1.1	10.4	8.9	14.6	23.5	11.2	12.3	14.9	14.5	128.0
Brownsville	1.3	1.2	1.1	1.4	2.5	2.6	1.9	2.6	5.5	3.2	1.8	1.6	26.6
Camaguey	1.5	1.4	2.4	3.6	7.6	10.5	5.6	5.5	7.3	5.4	3.1	2.0	56.1
Ciudad Trujillo	2.4	2.4	1.9	3.9	6.8	6.2	6.4	6.3	7.3	6.0	4.9	2.4	55.8
CRISTOBAL	3.4	1.5	1.5	4.1	12.5	13.9	15.6	15.3	12.8	15.8	22.3	11.7	130.4
David	1.2	0.8	1.2	2.6	11.4	9.8	10.9	10.6	13.2	14.7	13.6	3.1	93.1
Habana	2.8	1.9	1.9	2.2	4.5	6.6	4.8	5.4	5.8	6.5	3.0	2.3	47.6
Kingston	0.9	0.7	1.0	1.2	4.2	4.0	1.5	3.4	4.4	7.0	2.8	1.6	35.5
Miami	2.5	2.0	2.4	3.4	7.1	7.4	5.3	6.4	8.9	9.0	3.3	1.7	59.4
Nassau	2.2	1.7	1.5	2.4	5.9	6.6	6.0	6.6	7.0	6.6	2.9	1.4	50.7
New Orleans	4.8	4.2	6.6	5.5	5.4	5.8	7.1	6.4	5.8	3.7	4.0	4.6	63.5
Port-au-Prince	1.2	2.4	3.4	6.3	9.2	4.0	2.8	5.7	7.0	6.6	3.5	1.3	53.3
Port of Spain	2.7	1.5	1.8	1.9	3.5	7.6	8.7	9.6	7.2	6.6	7.2	4.8	63.2
San José	0.6	0.2	0.8	1.8	9.0	9.5	8.3	9.5	12.0	11.8	5.8	1.6	70.8
San Juan	4.2	2.7	3.0	4.1	5.3	5.3	5.7	6.0	6.2	5.6	6.9	5.8	60.6
Santiago	1.2	0.7	1.5	2.8	6.0	5.1	2.2	3.8	6.0	8.5	3.9	1.2	42.9
Tela	8.3	6.9	5.4	2.8	2.7	6.0	5.8	7.7	8.9	11.1	16.9	12.1	94.6
Valladolid	2.2	1.1	1.1	2.9	4.8	5.8	5.6	6.3	7.0	5.7	1.9	2.1	46.5
Vera Cruz	0.9	0.6	0.3	0.8	2.0	9.6	13.7	11.8	13.6	6.0	3.5	1.0	63.9
Washington	3.4	2.6	3.4	3.2	3.9	3.4	4.1	4.5	4.4	3.0	2.8	2.8	41.4

\*No data available .

TABLE VII: MEAN CLOUDINESS (tenths of sky covered)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Acapulco	2.0	1.7	1.6	2.0	3.7	6.4	5.7	6.0	6.8	5.0	2.8	3.0	3.9
BALBOA HEIGHTS	4.8	4.8	5.0	6.3	7.6	8.0	7.6	7.7	7.7	7.7	7.6	6.3	6.8
Belize	4.9	4.5	3.3	3.9	4.4	4.9	4.9	4.8	5.4	5.6	5.4	5.5	4.8
Bluefields	7.1	6.1	5.7	5.4	6.8	7.8	8.3	6.7	6.6	6.4	6.8	6.7	6.7
Brownsville	6.5	6.3	6.1	5.9	5.4	4.7	4.5	4.3	5.1	4.4	5.7	6.4	5.4
Camaguey	3.7	3.4	3.1	4.0	4.6	4.7	4.2	3.2	3.8	3.8	4.5	3.6	3.9
Ciudad Trujillo	4.4	4.5	4.3	5.1	5.2	5.0	4.6	4.8	4.5	4.4	4.3	4.7	4.6
CRISTOBAL	5.9	5.5	5.8	6.4	7.8	7.9	8.0	7.6	7.1	7.4	7.6	6.8	7.0
David*	-	-	-	-	-	-	-	-	-	-	-	-	-
Habana	3.0	3.0	3.0	2.0	3.0	4.0	4.0	4.0	4.0	5.2	4.0	4.0	4.0
Kingston	4.8	5.4	6.0	6.4	6.8	7.0	6.1	7.0	7.9	7.5	7.1	5.2	6.4
Miami	5.1	4.7	4.7	4.9	5.4	6.3	6.1	5.9	6.2	5.8	5.3	5.2	5.5
Nassau	5.4	5.3	5.1	5.2	6.0	6.2	5.9	5.9	5.9	5.9	5.4	5.3	5.6
New Orleans	5.9	6.2	6.1	5.6	5.0	5.6	6.5	5.6	5.4	3.7	5.1	6.1	5.6
Port-au-Prince	2.6	3.2	3.7	4.6	5.3	4.8	4.2	4.4	4.8	4.7	3.8	2.8	4.1
Port of Spain	5.5	5.3	5.6	5.6	5.9	6.9	6.6	6.6	6.6	6.4	6.1	5.5	6.1
San Jose	4.1	4.6	5.7	6.5	7.9	8.0	7.1	7.7	7.8	8.3	6.5	6.0	6.7
San Juan	4.6	4.4	4.2	4.6	5.1	5.1	4.8	4.1	4.4	4.4	4.4	4.5	4.6
Santiago	2.3	2.6	2.4	3.0	4.1	3.9	3.1	2.9	3.0	3.9	3.9	2.7	3.2
Tela	6.2	5.3	5.6	5.0	6.1	7.0	7.2	6.9	6.9	7.5	7.5	7.5	6.6
Valladolid*	-	-	-	-	-	-	-	-	-	-	-	-	-
Vera Cruz	6.1	5.9	5.4	5.2	5.5	6.3	6.4	6.2	6.6	6.0	6.2	6.1	6.0
Washington	6.1	5.6	5.6	5.4	5.4	5.1	5.1	5.1	4.8	4.6	5.3	5.8	5.3

TABLE VIII: MEAN RELATIVE HUMIDITY (%)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Acapulco	79	78	77	77	75	79	79	79	82	80	80	80	79
BALBOA HEIGHTS	78	75	73	77	85	87	86	87	87	88	88	84	83
Belize	80	80	80	79	81	83	81	81	80	78	82	81	81
Bluefields*	-	-	-	-	-	-	-	-	-	-	-	-	-
Brownsville	66	64	61	59	60	60	57	55	61	58	64	65	61
Camaguey*	-	-	-	-	-	-	-	-	-	-	-	-	-
Ciudad Trujillo	73	70	73	74	76	76	77	77	76	76	76	73	75
CRISTOBAL	78	77	77	79	83	85	86	86	85	85	86	82	82
David*	-	-	-	-	-	-	-	-	-	-	-	-	-
Habana	64	61	58	58	62	65	62	64	66	68	65	64	63
Kingston	62	62	62	65	69	67	64	67	69	71	69	64	66
Miami	59	55	55	56	57	62	64	62	66	63	60	60	60
Nassau	76	74	71	71	73	73	72	72	73	74	74	75	73
New Orleans	67	64	60	59	58	60	64	63	62	58	60	67	62
Port-au-Prince	63	63	63	68	72	67	64	68	72	74	72	67	68
Port of Spain	68	63	62	60	60	66	73	73	74	72	74	73	68
San Jose	76	72	72	73	81	84	83	84	86	87	80	80	80
San Juan	79	78	77	78	80	82	81	81	82	83	82	80	80
Santiago*	-	-	-	-	-	-	-	-	-	-	-	-	-
Tela*	-	-	-	-	-	-	-	-	-	-	-	-	-
Valladolid*	-	-	-	-	-	-	-	-	-	-	-	-	-
Vera Cruz	81	83	83	81	80	81	81	79	80	77	78	80	80
Washington	56	52	48	45	48	52	52	53	53	50	51	55	51

\*No data available

TABLE IX: MEAN WIND SPEED (MPH)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Acapulco	12.0	12.0	13.0	12.0	13.0	15.0	12.0	14.0	13.0	14.0	12.0	10.0	13.0
BALBOA HEIGHTS	8.8	10.1	10.3	8.8	6.1	5.4	5.9	5.9	5.6	6.3	5.8	6.4	7.1
Belize	11.0	12.0	14.0	14.0	14.0	15.0	13.0	12.0	12.0	10.0	10.0	11.0	12.0
Bluefields	5.0	4.0	4.0	4.0	3.0	3.0	6.0	5.0	4.0	3.0	5.0	5.0	4.0
Brownsville	11.0	11.3	12.3	12.5	11.9	11.1	10.1	9.5	8.5	8.6	9.9	10.2	10.6
Camaguey*	-	-	-	-	-	-	-	-	-	-	-	-	-
Ciudad Trujillo	9.0	8.0	9.0	9.0	8.0	9.0	9.0	8.0	8.0	8.0	9.0	10.0	9.0
CRISTOBAL	14.1	14.8	14.8	12.5	8.0	6.6	8.1	7.9	6.1	6.6	8.0	11.8	9.9
David	5.0	6.0	9.0	8.0	6.0	7.0	5.0	9.0	6.0	5.0	4.0	5.0	6.0
Habana	8.0	8.0	9.0	9.0	8.0	7.0	7.0	7.0	6.0	8.0	9.0	8.0	8.0
Kingston	7.0	7.0	8.0	8.0	9.0	10.0	9.0	8.0	7.0	6.0	6.0	6.0	8.0
Miami	13.5	13.5	14.2	13.9	12.1	10.9	10.4	10.2	10.2	13.2	12.7	12.9	12.3
Nassau	8.8	8.8	8.8	8.8	6.9	6.1	5.6	6.1	5.6	7.8	8.8	9.2	7.6
New Orleans	8.3	8.7	8.8	8.4	7.5	6.9	6.4	6.4	7.4	7.7	8.0	8.2	7.7
Port-au-Prince	6.4	6.4	6.8	6.4	6.1	7.3	7.2	6.4	5.7	5.1	5.3	5.7	6.2
Port of Spain	4.1	5.0	4.8	5.6	5.6	4.4	4.1	3.6	3.9	3.8	3.7	3.7	4.4
San Jose	11.1	12.4	10.1	9.8	5.3	4.4	5.3	4.7	4.4	4.1	6.6	8.2	7.2
San Juan	12.0	11.0	12.0	12.0	11.0	12.0	13.0	12.0	10.0	9.0	10.0	12.0	11.0
Santiago	4.0	4.0	4.0	4.0	3.0	3.0	4.0	4.0	3.0	4.0	5.0	4.0	4.0
Tela	5.0	6.0	5.0	5.0	5.0	5.0	7.0	7.0	5.0	5.0	6.0	4.0	5.0
Valladolid	5.6	5.6	6.3	6.9	5.6	5.6	4.7	4.7	4.5	4.3	4.5	4.7	5.4
Vera Cruz	25.3	15.6	18.1	14.3	9.8	10.0	10.7	9.2	18.6	22.6	18.5	23.3	20.6
Washington	7.7	8.5	8.9	8.3	7.0	6.4	5.7	5.7	5.9	6.2	7.3	7.3	7.1

\*No data available

## APPENDIX B

### Map:

- Figure 2: Station Locations
- Figure 3: Mean Temperature, Warmest Month
- Figure 4: Mean Daily Maximum Temperature, Warmest Month
- Figure 5: Mean Temperature, Coldest Month
- Figure 6: Mean Daily Minimum Temperature, Coldest Month
- Figure 7: Mean Daily Temperature Range, Warmest Month
- Figure 8: Mean Annual Precipitation
- Figure 9: Mean Precipitation, Wettest Month
- Figure 10: Number of Wet Months
- Figure 11: Mean Relative Humidity, Driest Month
- Figure 12: Mean Cloudiness, Wettest Month
- Figure 13: Mean Wind Speed, Wettest Month
- Figure 14: Composite of Analogous Areas - Balboa Heights
- Figure 15: Composite of Analogous Areas - Cristobal

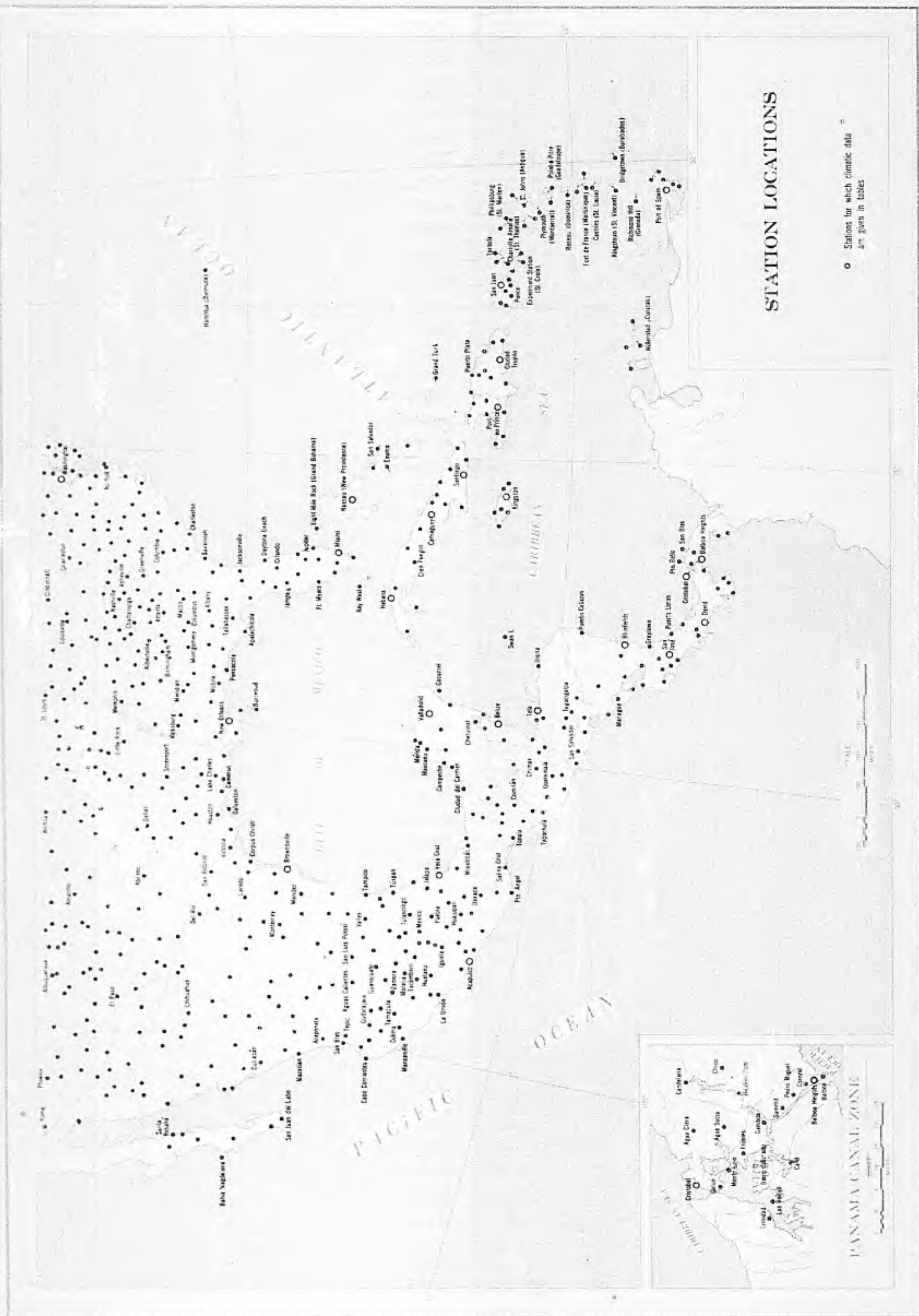


Figure 2



# CLIMATIC ANALOGS OF PANAMA CANAL ZONE - MIDDLE AMERICA

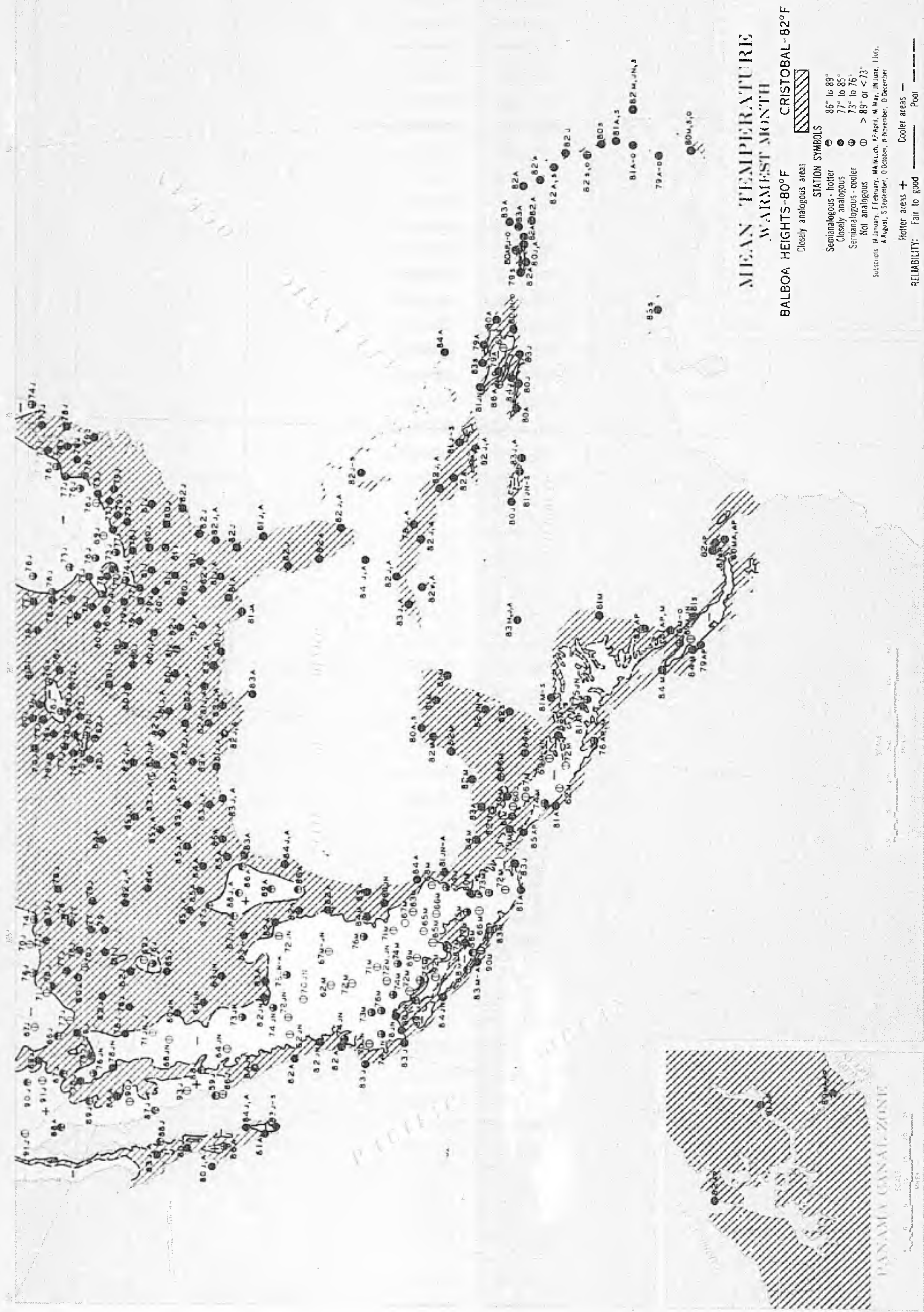


Figure 3

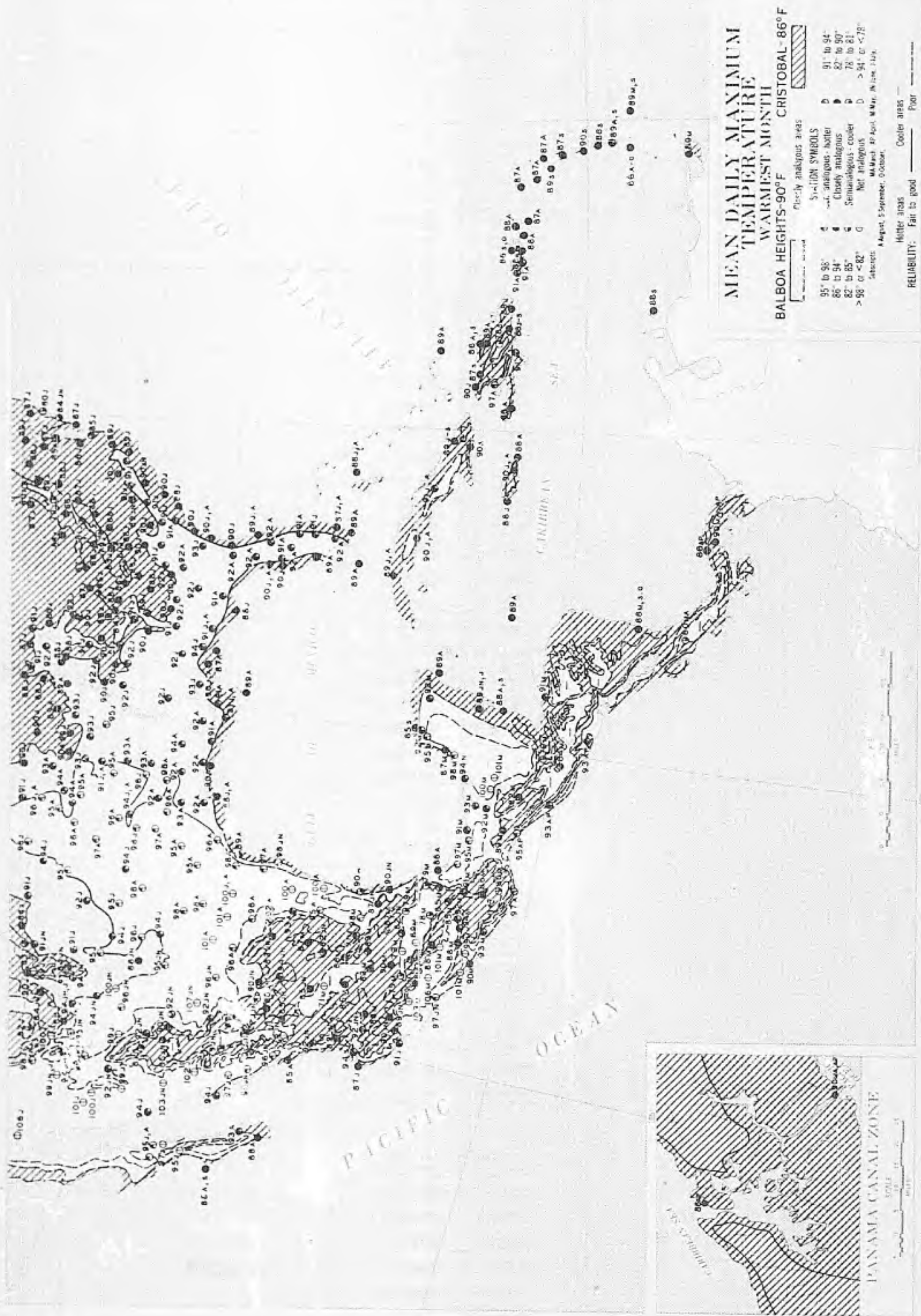


Figure 4



# CLIMATIC ANALOGS OF PANAMA CANAL ZONE - MIDDLE AMERICA

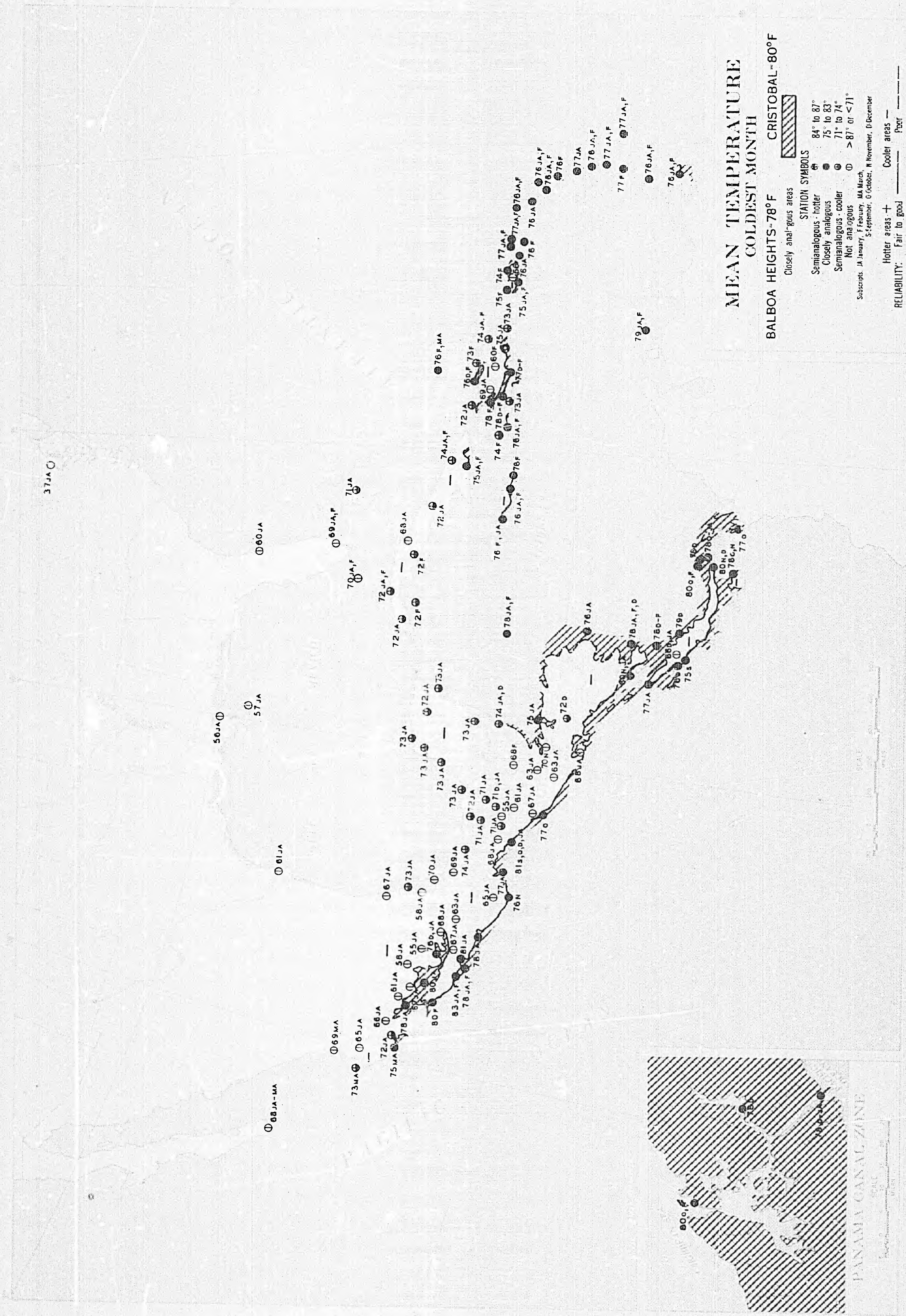


Figure 5



[illegible]

Figure 6

## CLIMATIC ANALOGS OF PANAMA CANAL ZONE - MIDDLE AMERICA

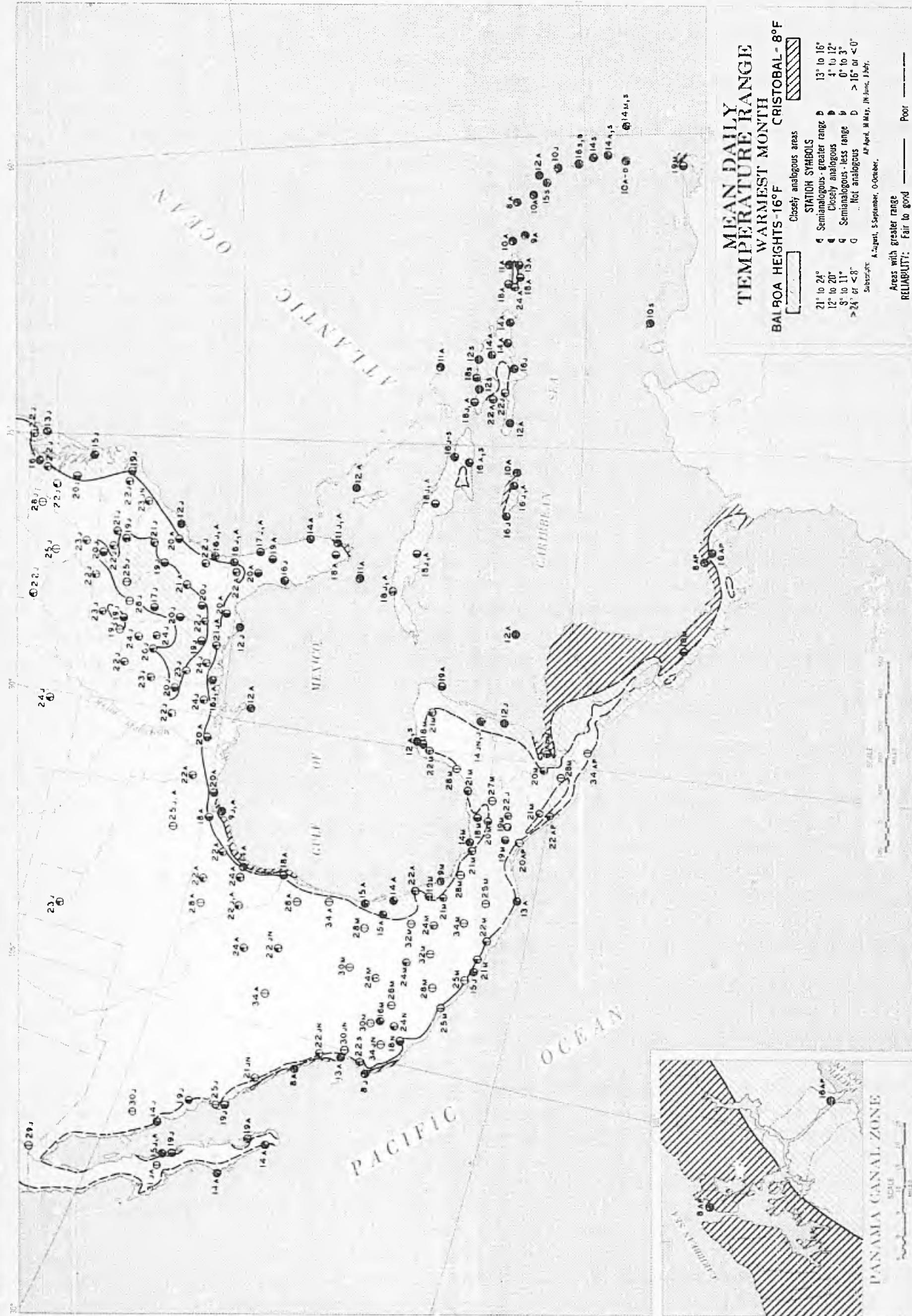


Figure 7



# CLIMATIC ANALOGS OF PANAMA CANAL ZONE - MIDDLE AMERICA

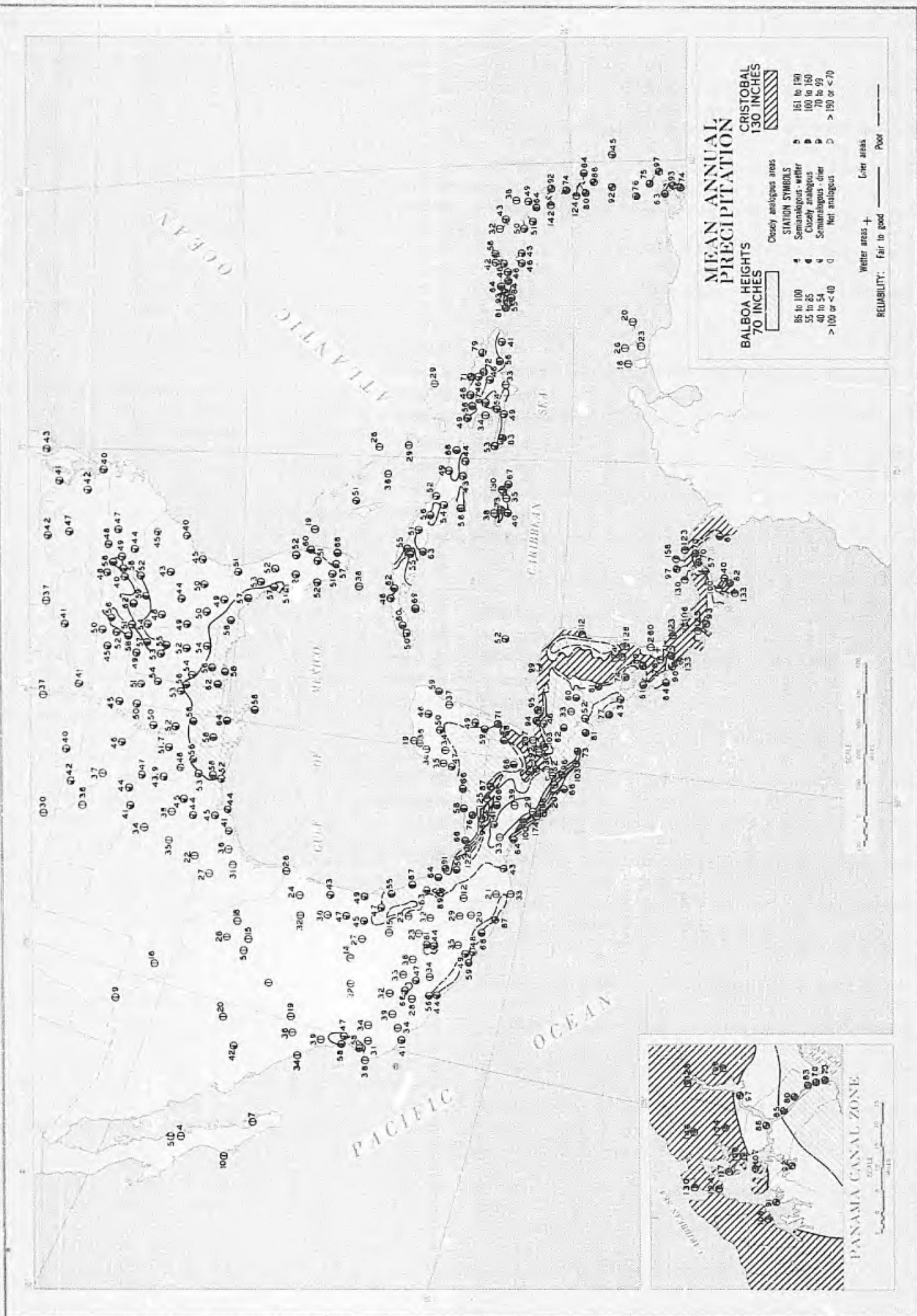


Figure 8



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1994年4月26日



# CLIMATIC ANALOGS OF PANAMA CANAL ZONE - MIDDLE AMERICA

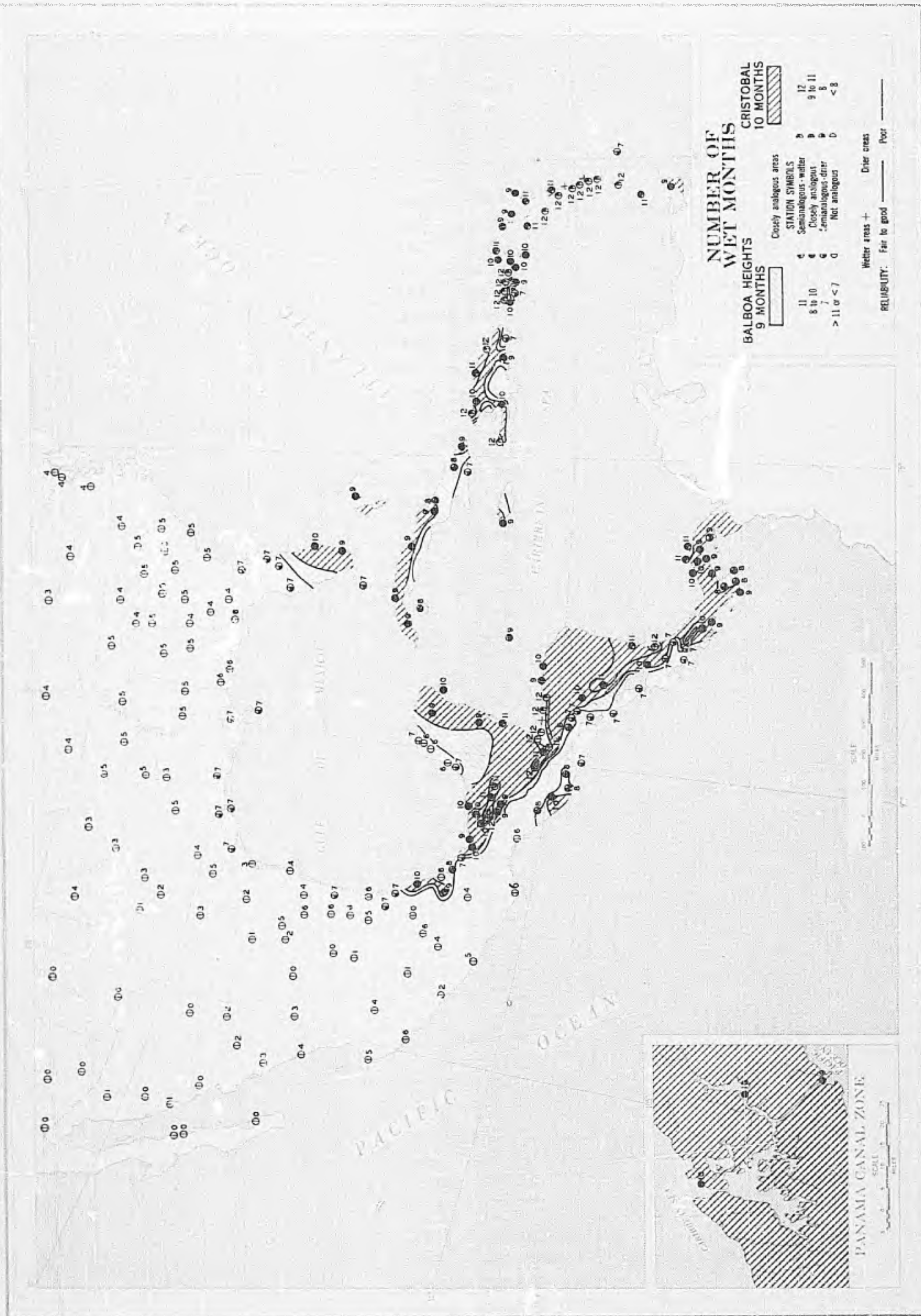
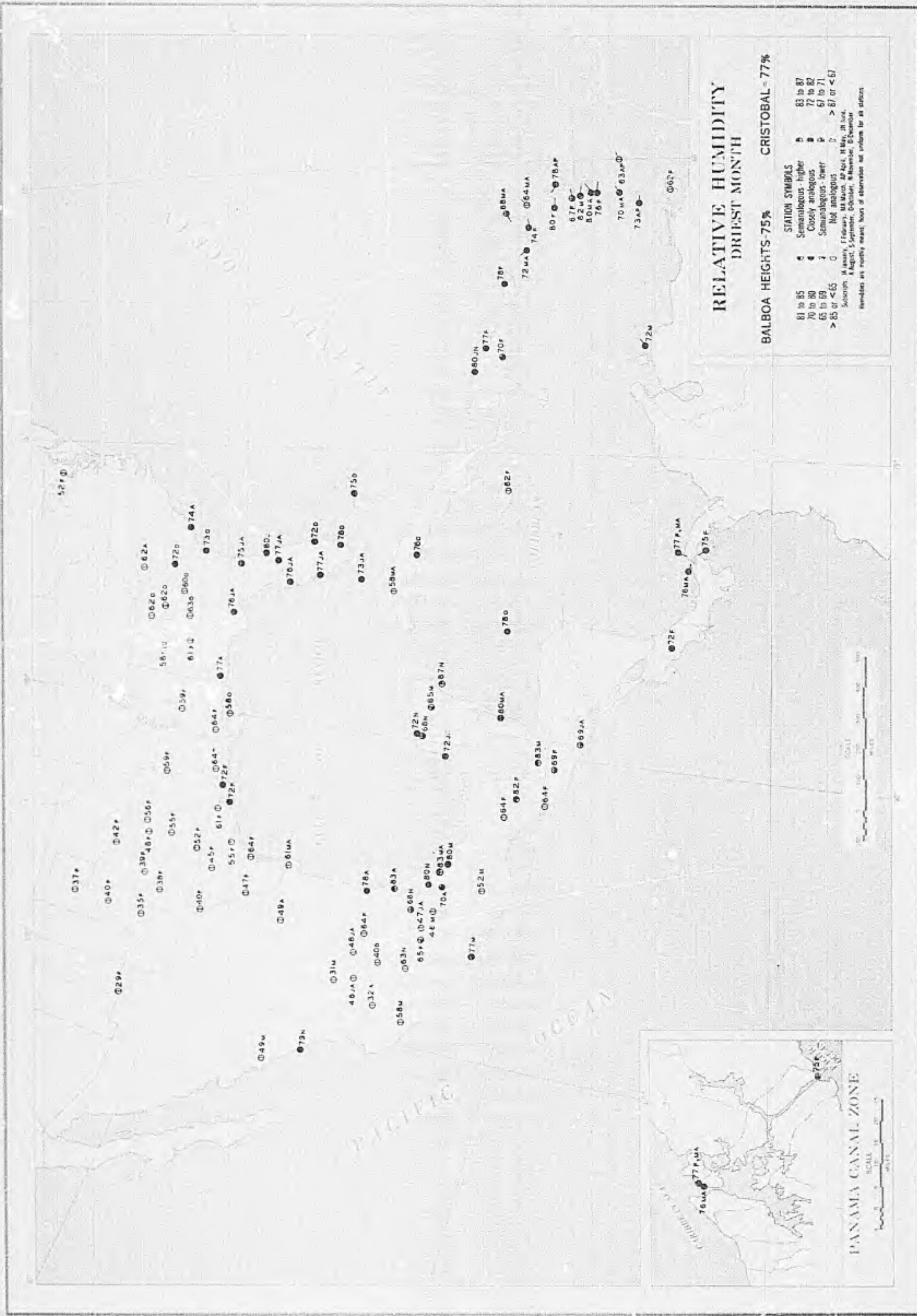


Figure 10



# CLIMATIC ANALOGS OF PANAMA CANAL ZONE - MIDDLE AMERICA





# CLIMATIC ANALOGS OF PANAMA CANAL ZONE - MIDDLE AMERICA

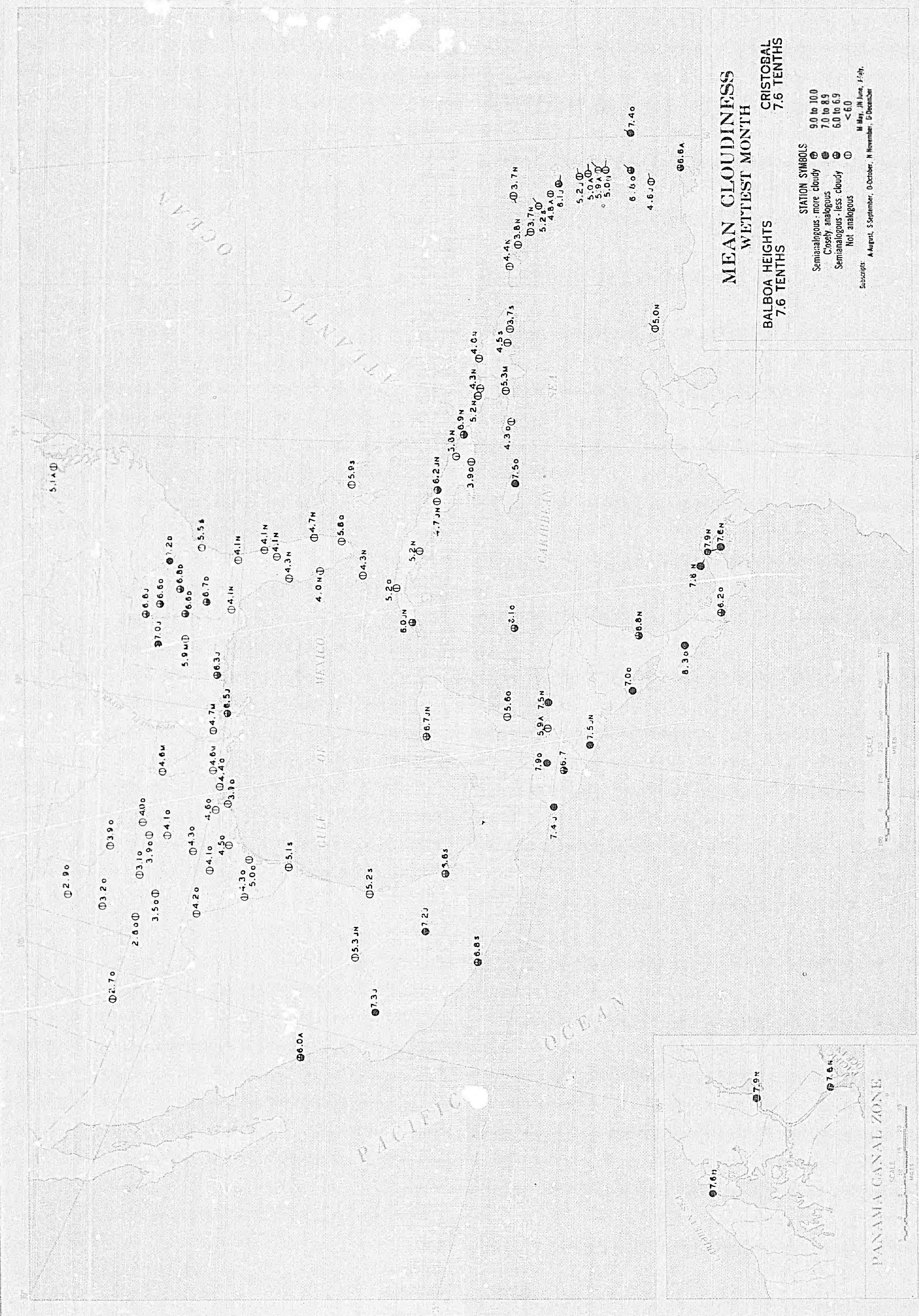
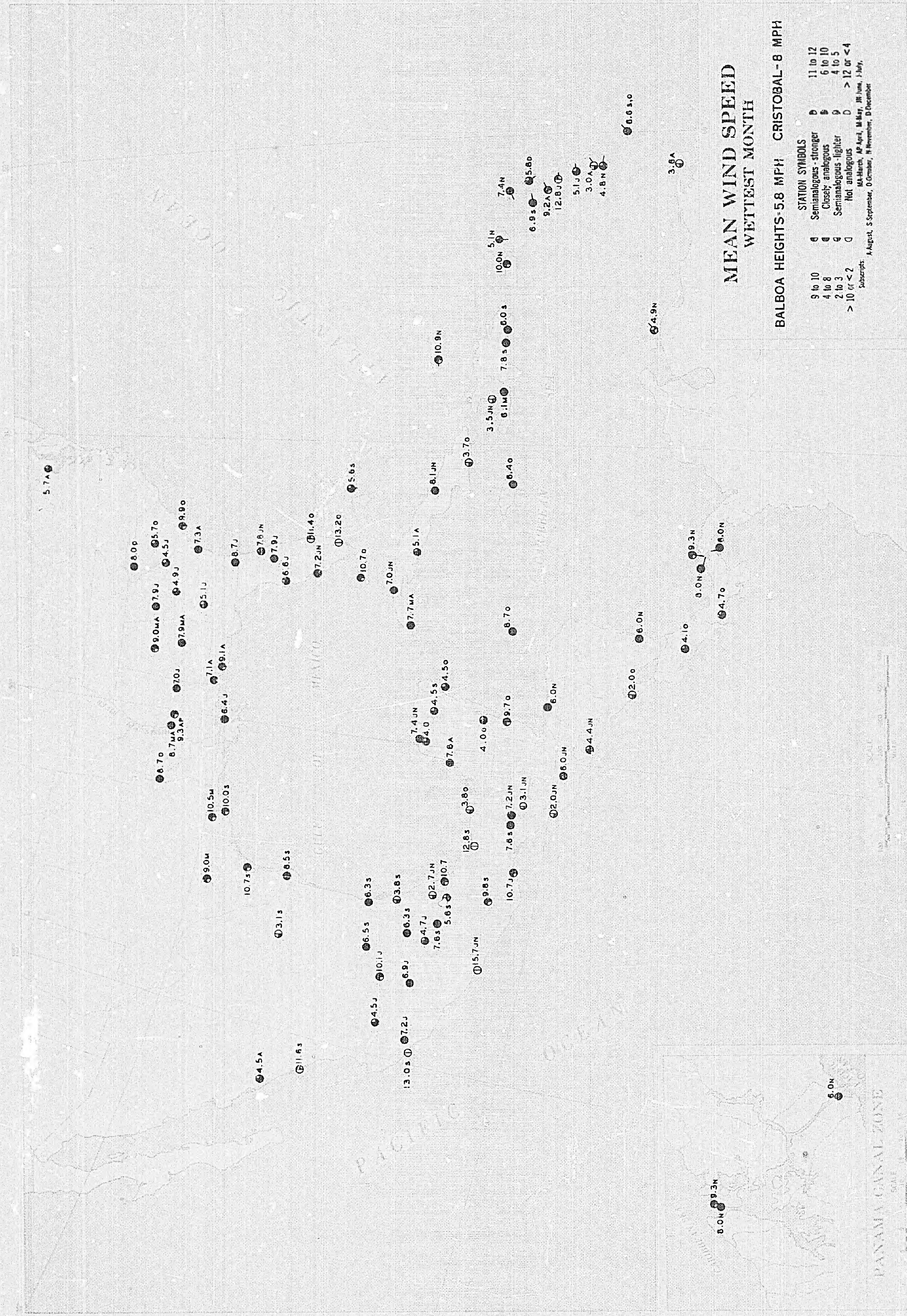


Figure 12







# CLIMATIC ANALOGS OF PANAMA CANAL ZONE - MIDDLE AMERICA

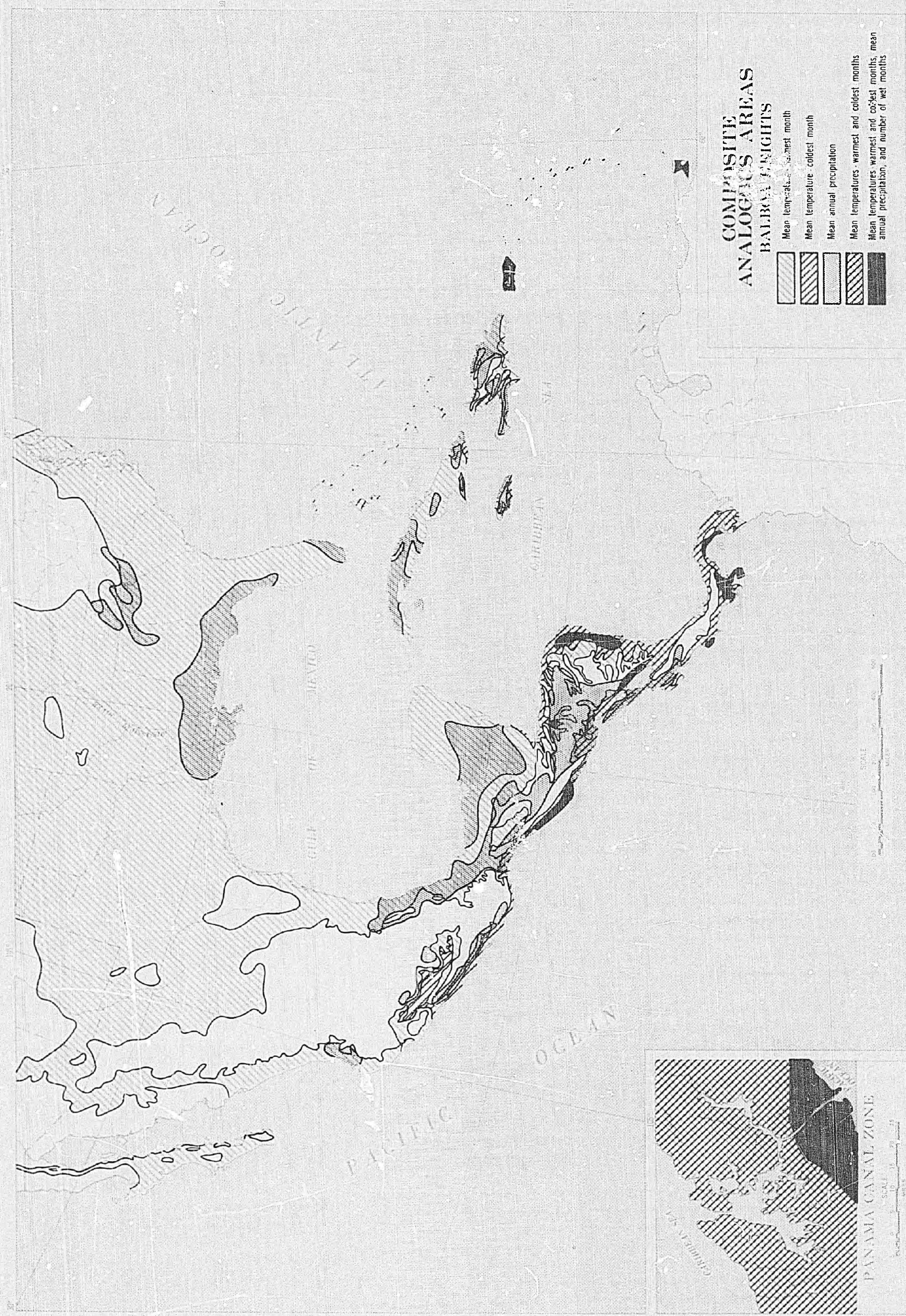


Figure 14



# CLIMATIC ANALYSIS OF PANAMA CANAL ZONE - MIDDLE AMERICA



Figure 15



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